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APPLE BLOTCH AND ITS CONTROL.

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INTRODUCTION.

In the more southern apple-growing sections of the United States the disease known as apple blotch is one of the most destructive with which orchardists have to contend. It first came generally to the notice of plant pathologists about 15 years ago and soon afterwards was regarded as important throughout southern apple-growing sections. As early as 1895 the disease was recognized by Mr. M. B. Waite, pathologist of the Bureau of Plant Industry. He photographed the diseased fruits and determined the organism present to be a species of Phyllosticta. His photographs, which are on file in the Office of Fruit-Disease Investigations, show that he was working with typical specimens of the disease. The fact that blotch was previously confused with apple scab by growers, because both of these diseases occur comparatively early in the season, accounts for the rather late recognition of its importance.

Blotch is not so universally distributed, even throughout the South, as scab. While in some sections it will be found in practically every

NOTE.—This bulletin is of interest to plant pathologists and to the apple growers of the eastern half of the United States, especially those of the more southerly apple-growing sections.

orchard, in other sections it is only locally severe. The former is the case in the Ozarks of Missouri and Arkansas and in the commercial apple-growing sections of Kansas, while the latter is true in Virginia and Maryland.

On account of the above-mentioned facts it is very difficult to compute the amount of damage caused by the disease, but it is probable that $2,000,000 would be a conservative estimate of the annual loss due to it.

In orchards in which blotch has not been placed under control by spraying, the entire crop of susceptible varieties may succumb to the disease and the trees themselves may be severely injured, in extreme cases even killed. Losses of 50 to 75 per cent of the entire crop are common in some sections.

The disease is found in practically all the eastern and middle-western apple-growing regions from Pennsylvania, Ohio, Indiana, Illinois, northern Missouri, and Nebraska southward. It is most serious and widely prevalent in Kansas, southern Missouri, northern Arkansas, Tennessee, and Kentucky. It is also a serious disease in fruit-growing sections bordering on or near the Ohio River. In Virginia and Maryland it is only locally severe, but it has become much more prevalent during the last two years. Blotch has been gradually extending farther north, but should not become serious in properly sprayed orchards. In those sections which have been free from the disease and in which a fungicide such as lime-sulphur solution or Bordeaux mixture is annually applied to apple trees about three weeks after the petals have fallen, blotch should not be able to gain a foothold.

DESCRIPTION OF APPLE BLOTCH.

Blotch occurs on the fruit, foliage, and twigs of the apple.

On the fruit it first appears as small dark, somewhat raised spots, which later enlarge slowly. Usually these spots have in midseason a dark fringed or stellate appearance, though on some varieties, such as Maiden Blush, the center of the spots may be somewhat more raised or blisterlike in appearance and of rather light color, due to the raised cuticle (Pl. I, figs. 2 and 3).

A later phase of this disease on the fruit is the coalescence of several spots, a general homogeneous darkening, with complete elimination of the stellate configuration typical of earlier stages. On some varieties, notably Ben Davis, a cracking open of the fruit often in three directions from a central point, is very common in orchards in which the disease is at all serious (Pl. I, fig. 1).

A characteristic spot is raised, glistening black, with margins so deeply cut in and so irregular as to give the spot its commonly noted stellate appearance (Pl. I, fig. 4). The tissues beneath the epi-

dermis are not invaded directly and are affected only indirectly as the diseased epidermis may permit the entrance of rot organisms or as extensive cracking may affect the flesh. Not only may the fruit be cracked open and otherwise made unsightly by the disease, but in severe cases it may be so dwarfed and distorted as to be wholly worthless. Even on very young spots the tiny glistening pycnidia of the causal fungus are always in evidence.

On the leaves (Pl. II, figs. 1 and 2) the disease appears as small nearly white spots scarcely more than a millimeter in diameter. Usually a single pycnidium of the fungus is to be found near the center of the spot. Under ordinary conditions blotch is not to be considered a serious foliage disease, but in cases where an orchard is severely infected the spots on the leaves are numerous enough to affect seriously the synthesis of carbohydrates and even cause defoliation.

On the young twigs and water sprouts the disease is first noticed as a dark raised area, soon dotted with numerous pycnidia. Later the infected part becomes somewhat sunken. As the twig becomes more mature the infected portion becomes lighter colored, and during the next season the diseased area will appear as an older tan-colored portion surrounded by a newer dark-colored area (Pl. II, figs. 3 and 4). In the older portion the fungus is dead, but in the newer portion it will be found alive, extending the previous year's destruction. In ordinary cases not many twigs are killed and few are badly injured (Pl. II, fig. 6); but in sections in which the disease is severe, and especially on certain varieties, such as the Northwestern (*Northwestern Greening*), the infection may be so severe as actually to kill the tree.

The fruit spurs may be attacked and in extreme cases even killed. In uncared-for orchards or in orchards in which the disease has been very prevalent and without proper control by means of spraying, many of the fruit spurs may be injured seriously.

CAUSE OF THE DISEASE.

The cause of the disease is the fungus *Phyllosticta solitaria*, first described by Ellis and Everhart (2)[1] in 1895. The type specimen was found on the leaves of the wild crab apple (*Pyrus coronaria* L.). The specific name is suggestive of the tendency of the fungus to form a single pycnidium in each spot on the leaf.

REVIEW OF THE LITERATURE.

In 1902 Clinton (1) published a description of the disease as it occurs on the fruit of the apple and considered it due to an unknown species of Phyllosticta. He also noted that pycnidia on the fruit produced fewer spores as the season advanced.

[1] The serial numbers in parentheses refer to "Literature cited," p. 11.

In 1907 Scott and Quaintance (5) described the disease and gave tentative recommendations for its control.

The first extensive report on the life history of the fungus and the first definite recommendations for its control were published by Scott and Rorer (6) in 1907. Later (1909), by comparison with type specimens they identified the fungus definitely as *Phyllosticta solitaria* E. and E. and determined by cross inoculations that the fungus found on leaves, fruit, and twigs is identical. They further determined that the fungus passes from one season to another in small cankers on the twigs.

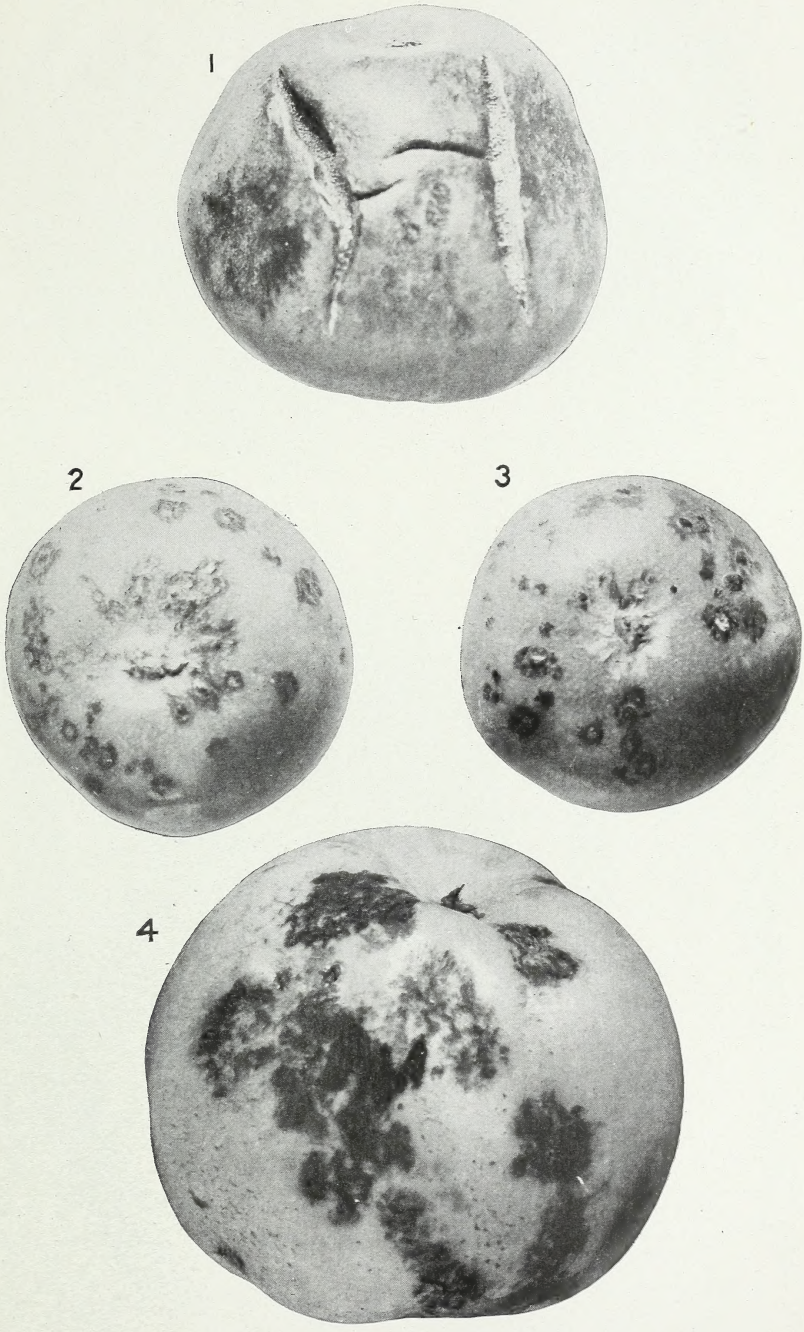
Sheldon (7) in 1907 reported the presence of the fungus on twigs. He was the first to identify the fungus as *Phyllosticta solitaria* E. and E. and gave a good description of the disease on leaves, fruit, and twigs.

Lewis (3) gave a detailed description of the disease on the fruits of different varieties and noted particularly the destruction of fruit spurs.

THE FUNGUS.

The life history of the causal organism has been traced by Scott and Rorer and by Sheldon. They found that the fungus passes the winter alive in the small twig cankers, where it grows and develops spores the following spring. From this source the young fruit, leaves, and twigs become infected early in the season. Later, spores from the spots of apples thus affected may spread the disease farther during the current season.

Scott and Rorer found almost no spores in mummied fruits of the preceding year and concluded that mummies were not a source of the spring infections. At different times during the spring of 1915 the writer undertook to examine for spores something more than a bushel of mummied fruits that had been badly affected with blotch during the preceding year. The varieties selected were Ben Davis and Missouri (*Missouri Pippin*), both of which are very susceptible to the disease. On the average, six blotched areas on each apple, especially selected for the large number of pycnidia contained in them, were examined. The period during which the mummied fruits were collected and examined extended from April 1 to June 1, 1915. The fruits were from trees particularly noted during the preceding year as heavily infected with the disease. It was thought that by examining such specimens at intervals during this period it could be ascertained (1) whether spores remained in the pycindia through the winter, (2) whether an ascogenous form was produced during the winter or spring, and (3) whether new pycnidia with spores were produced after the growing season started in the spring. All the material was sectioned on the freezing microtome and examined care-



APPLE BLOTCH.

1, Ben Davis apple, showing cracking due to blotch, Bentonville, Ark., August 10, 1914; 2 and 3, Maiden Blush apples affected with blotch, Anderson, Mo., July 8, 1915; 4, Yellow Newtown apple affected with blotch, Greenwood, Va., August 6, 1916.

APPLE LEAVES AND TWIGS SHOWING BLOTCH.

1 and 2, Leaves of the Arkansas Black variety, with spots caused by the blotch fungus, Centerton, Ark., July 31, 1915; 3, 1-year-old blotch canker on Ben Davis apple twig, Bentonville, Ark., 1914; 4, 2-year-old blotch canker on Ben Davis apple twig, Bentonville, Ark., 1914; 5, leaf of the Missouri variety, showing lesions on petiole and midrib produced by artificial inoculation with spores of *Phyllosticta solitaria* from pure cultures; 6, an older blotch canker on a Ben Davis twig, Bentonville, Ark., September 9, 1916.

fully under the microscope. In the old pycnidia no spores were found. No ascogenous stage and no newly formed pycnidia were discovered. The fungus appears to be in no way saprophytic, since not only does it fail to live over on decayed fruits, but it dies out in the older parts of the twig cankers, living only along the margins and dying out entirely in the third or fourth year as the twig becomes more woody.

In order to confirm the cross-inoculation experiments of Scott and Rorer, in which the disease was produced on the fruit by spores from twig lesions and on the twigs by spores from diseased fruits, the writer undertook a series of experiments differing from those of Scott and Rorer in that the latter used spores taken directly from twig lesions and diseased fruits, whereas those of the writer were made with spores from pure cultures from those sources. The fungus isolated from twigs and fruits from Kansas was grown on sterile apple twigs in pure culture, and when the spores were mature a suspension of them in sterile water was sprayed on leaves, fruit, and twigs. Inoculations were made on twigs, water sprouts, and fruits of the Missouri variety on July 6. On August 7 typical blotch spots began to appear on the leaf blades and petioles, with an abundance of fertile pycnidia in the dark sunken lesions on the petioles and midribs (Pl. II, fig. 5). Minute spots on the fruits also were beginning to appear. On September 6 the spots on leaves and fruits were numerous and conspicuous. The disease was beginning to appear also on the twigs and water sprouts. By September 14 lesions on the stem portion of the water sprouts and twigs were appearing abundantly. These were black raised areas, bearing numerous pycnidia filled with spores, and were only on the younger portions of the twigs and water sprouts. The fungus was reisolated from leaves, fruit, and twigs and reidentified as *Phyllosticta solitaria.*

The writer at various times has attempted to infect the fruit in August and September with spores from pure cultures, but without success. Apparently fruit and twigs become resistant as they grow older, possibly through the increasing impermeability of the epidermis and the changing of stomata to lenticels. The heaviest infections on fruit occur early in the season, decreasing as the season advances. This is due, not only to a decrease in the number of spores produced by the fungus in the cankers and fruit, but probably in a much greater degree to the previously mentioned increased resistance on the part of the fruit. The writer has never been able to inoculate fruits of Ben Davis and Missouri after August 1 by spraying them with a suspension of spores in distilled water. It may be noted also that at that time the natural supply of spores capable of infecting is still not wholly wanting in so far as those produced from cankers

are concerned, while many are still produced from the diseased fruits.

It is a rather curious thing that leaf infections are comparatively rare in Arkansas, whereas in Kansas they are rather abundant. This may be partly, though not wholly, accounted for by the more numerous cankers and consequent heavier infection in Kansas orchards.

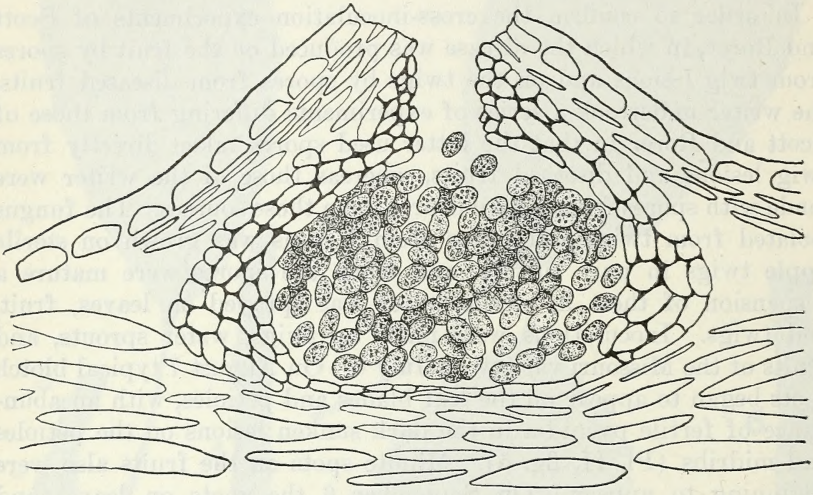


FIG. 1.—Section through a pycnidium of *Phyllosticta solitaria* produced in 1914 on a blotched spot of a young Ben Davis apple.

The fruiting bodies (pycnidia) are found on the newer parts of the twig cankers until the cankers are about 4 years old. They are most plentiful on young cankers which had begun their development during the previous season. They occur on the leaves also, particularly in the lesions on the midrib and petiole, and in the blotches on the fruits. The pycnidia (fig. 1) are rather small, black, glistening, subglobose or somewhat depressed, varying from 75 to 250 μ in diameter. When mature they are filled with spores, but those formed late in the season usually fail to mature. The period of maximum pycnidium production is in May on the twigs and in late June and early July on the fruit and leaves. Those on the leaves rarely produce spores.

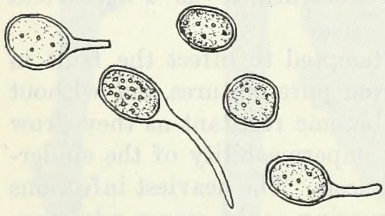


FIG. 2.—Spores of *Phyllosticta solitaria* from twig cankers of the Ben Davis apple. Bentonville, Ark., May 25, 1914.

The spores (fig. 2) are hyaline, one celled, and when mature are filled with rather large, uniform-sized, often closely compacted granules. They are oval to subglobose and measure 8 to 10 by 5.5 to

6.5 μ. When newly formed it is easy to demonstrate the presence of a gelatinous covering about the spore, especially when, as is often the case, it is prolonged into a stout hyaline appendage (fig. 2). The spores (fig. 3) germinate in 15 to 20 hours. The germ tube is somewhat darker than the spore and usually shows a pronounced thickening at the point of emergence (fig. 3). More than one germ tube may issue from a single spore (fig. 3).

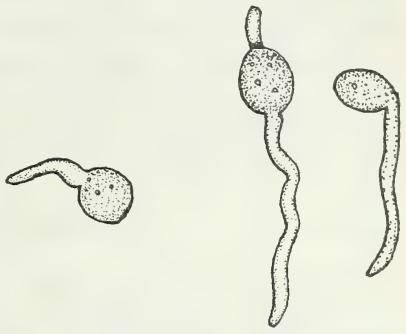


FIG. 3.—Germinating spores of *Phyllosticta solitaria*. Spores from Ben Davis twig cankers. May 25, 1914.

Spores from the twig cankers in which the fungus has passed the winter are usually mature and ready to infect the young fruit and leaves about three weeks after the petals have fallen. This was first determined by Scott and Rorer by noting the latest time at which spraying would effectively prevent infection. The time of infection was directly determined by the writer during the seasons of 1914 and 1915 by germination tests of spores from twig cankers. Table I shows the results of such tests.

TABLE I.—*Results of germination tests of spores of apple blotch from twig cankers.*

Date.	Germinating spores.	Date.	Germinating spores.	Date.	Germinating spores.
1914.	*Per cent.*	1914.	*Per cent.*	1915.	*Per cent.*
Apr. 30	0	May 15	0	May 13	10
May 1	0	May 21	0	May 17	20
May 6	0	May 23	75	May 21	20
May 8	0	May 25	75	May 24	75
May 9	2	May 29	75	May 28	75

For each test, pycnidia were scraped from the newer portions (the current year's growth) of young twig cankers. These pycnidia were then examined under the microscope for spores. If spores were sufficiently abundant and appeared to be mature, they were suspended in distilled water in Van Tieghem cells and the percentage of germinating spores was noted daily for periods ranging from three to five days. As the spores when mature usually germinate within 24 hours, it was really unnecessary to prolong the attempted germination over so long a period. The cankered twigs used in this work in 1915 were collected from the same trees as those used in 1914.

During both seasons the time of petal fall was April 28. As these two seasons were about average ones, it is evident that in the Ozarks

the first spraying for the prevention of blotch infections should be well under way when three weeks have elapsed after petal fall. This is particularly true during a season of belated blooming due to cold or otherwise unseasonable weather, as the period of growth and maturity of the fungus and its spores does not seem to be influenced so much by such conditions as does the blooming period of the host.

As determined by artificial inoculations, *Phyllosticta solitaria* grows very slowly and is not perceptible on the fruit until three to six weeks after infection has taken place. Ordinarily the blotched areas are not large enough to appear conspicuous before the early part of July.

CULTURAL RELATIONS.

Phyllosticta solitaria will grow on a wide range of culture media. It will also produce pycnidia on all of the ordinary solid culture media. These pycnidia, however, do not produce spores. The only medium on which the writer has been able to grow the fungus with the formation of both pycnidia and spores is sterile apple wood, which was the medium used by Scott and Rorer. Even on this medium two to three months elapsed in the case of all the strains used by the writer before mature spores were produced.

WEATHER CONDITIONS.

In orchards in which twig cankers are abundant, dry weather does not appear to reduce greatly the number of infections, because practically every apple is affected anyway; but in the average blotch-infected orchard of the Ozark section the reduction is very noticeable. In 1914 the absence of rain during the latter half of May and during the first three weeks of June greatly reduced the number of infections. In Arkansas the period of heaviest infection did not occur until about July 1. In Kansas, where blotch is a particularly serious disease, it was found, as Lewis had noted previously in dry seasons, that the disease was not greatly hindered by the dry weather. The sources of infection, that is, twig cankers, are much more abundant in Kansas than in Arkansas, and even if a large proportion of the expelled spores failed to germinate there would still be enough to infect the fruit heavily. Undoubtedly, as in the case of most fungous diseases, moist weather is particularly favorable for the occurrence of the maximum number of blotch infections.

The writer has never been able to note any relation between the amount of infection and the temperature extremes during May and June. Neither extreme appears to be particularly favorable or particularly unfavorable.

RELATIVE SUSCEPTIBILITY OF APPLE VARIETIES.

The list of susceptible, moderately susceptible, and resistant varieties shown in Table II is based on the publications of Scott and Rorer and of Lewis and upon the writer's own observations. It often occurs that a variety which is quite resistant and which has no twig cankers of its own will show some infections on the fruit if it is growing in close proximity to a badly infected variety.

TABLE II.—*List of apple varieties, showing their relative susceptibility to blotch infection.*

Very susceptible.		Moderately affected.		Resistant varieties.
Varieties.	Varieties.	Varieties.	Varieties.	
Missouri.	Gano.	Oldenburg.	McAfee.	Winesap.
Ben Davis.	Domine.	Benoni.	Ralls.	Jonathan.
Northwestern.	Huntsman.	Arkansas.	Yellow Bellflower.	York Imperial.
Limbertwig.	White Pearmain.	Bradford.	Northern Spy.	Givens.
Maiden Blush.	Smith.	Ingram.	Stayman Winesap.	
Lawver.	Tolman.	Collins.	Fink.	
Shockley.	Fameuse.	Rambo.	Minkler.	
Clayton.	Wagener.	Golden Russet.	Wealthy.	
Willow.	Gilpin.	Grimes.	Rome Beauty.	
Arkansas Black.		Yellow Newtown.		

REMEDIAL MEASURES.

Under ordinary conditions blotch is controlled rather easily by spraying, but under conditions of severe infection the spraying must be done with great promptness and thoroughness. In mild cases control is accomplished by spraying with lime-sulphur solution (32° to 34° Baumé) diluted at the rate of 1½ gallons to 50 gallons of water (or homemade lime-sulphur solution diluted to equal strength), but under conditions of severe infection lime-sulphur solution is not efficient. Under such conditions control is attained through the use of Bordeaux mixture containing 3 pounds of bluestone (copper sulphate) and 4 pounds of lime to 50 gallons of water. Where lime-sulphur gives adequate control it should be used, as it is less likely to injure the fruit and foliage than Bordeaux mixture. The first spraying for the control of this disease should be finished three weeks after the blossom petals have fallen, the second should occur three weeks later, and the third about 9 or 10 weeks after the petals fall.

By thorough spraying for three or four years, the number of twig cankers will be greatly reduced, making control much easier. The old cankers will die out after that length of time, and the coating of spray on the young twigs will prevent the formation of new ones.

In this way Mr. Leslie Pierce, of the Bureau of Plant Industry, and the writer greatly lessened the number of twig cankers and increased the ease of control in an orchard in northwestern Arkansas during 1913, 1914, and 1915.

This orchard, consisting of trees of Missouri, a very susceptible variety, was, prior to 1913, badly infected with blotch. In fact, previous to 1913 the orchard, mainly because of blotch, had not matured a crop. After three years of thorough spraying, done at the proper time, the trees are almost free from twig cankers and the disease is nearly eliminated from the orchard.

Spraying, then, not only prevents the infection of fruits during the current year, but tends also to lessen the number of possible infections during succeeding years. Furthermore, since, as the writer (4) has shown, the bitter-rot fungus may live through the winter in blotch cankers, the elimination of the latter may be an aid in the control of bitter-rot in orchards in which that disease is present.

SUMMARY.

(1) Apple blotch, a serious disease of the more southern apple-growing sections of the United States, affects the twigs, fruit, and leaves of the apple. It has been shown by previous investigators (Waite, Clinton, Sheldon, and Scott and Rorer) to be caused by the fungus *Phyllosticta solitaria*, which, as Sheldon and Scott and Rorer discovered, winters over in twig cankers and infects the young fruit, leaves, and twigs during the following year. Neither Scott and Rorer nor Lewis considered mummied fruit of the previous year an important source of infection.

(2) The writer has made successful cross inoculations on fruit, leaves, and twigs from pure cultures of the fungus obtained from naturally diseased fruit and twigs, thus confirming the inoculation work of Scott and Rorer, which, however, was not done by the use of pure cultures.

The reason so few infections occur late in the season is due to the increased resistance of the host, in addition to the fact that there is a gradual decrease in the number of spores produced by the causal fungus. A large number of mummied fruits were examined at intervals throughout the spring, but no spores were found. Hence it is concluded that mummies are not an important source of infection.

Wet weather favors blotch, but in orchards in which twig cankers are abundant the disease is not checked effectively by dry weather.

(3) The disease is controlled by three sprayings with 3–4–50 Bordeaux mixture at intervals of three weeks, the first of which should be completed about three weeks after the blossom petals have fallen. Summer-strength lime-sulphur solution may be substituted for Bordeaux mixture where the disease is not severe, thus lessening the risk of injury. The proper time for the first application has been determined both by spraying experiments and by spore germination tests in the laboratory. This spraying schedule differs only slightly from that originally worked out by Scott and Rorer.

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